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I hereby certify that this correspondence and identified enclosures are being deposited on April 25, 2000, with the U.S. Postal Service, "Express Mail Post Office to Address" service, No. EL502381464US, under 37 C.F.R. § 1.10, addressed to the Commissioner of Patents and Trademarks, Box PATENT APPLICATION, Washington, D.C. 20231.

Florence Thys-Doucet
Florence Thys-Doucet

Commissioner of Patents and Trademarks
Box PATENT APPLICATION
Washington, D.C. 20231

Re: Client: Allen & Gledhill
Matter No. 15939-18
U.S. Patent Application
Title: SPINDLE MOTOR WITH AN AERODYNAMIC
AND HYDRODYNAMIC BEARING ASSEMBLY

Subject: Transmitting Patent Application for Filing

Sir:

We enclose for filing the patent application of:

Inventor(s): Zhejie Liu, QiDe Zhang, Shixin Chen and Teck Seng Low

For: SPINDLE MOTOR WITH AN AERODYNAMIC
AND HYDRODYNAMIC BEARING ASSEMBLY

The application includes:

- Cover + 10 pages of specification, claims and abstract
- 5 sheet(s) of drawing(s)
- Signed Declaration and Petition
- Signed Power of Attorney
- Assignment of Rights

The filing fee has been calculated as shown below:

Assistant Commissioner for Patents

April 25, 2000

Page 2

	No. Filed	No. Extra	Small Entity	Other Than Small Entity	
Basic Fee	\$690.00		\$345		\$690
Total Claims	7				
Ind. Claims	1				
Multiple Dependent Claims					
TOTAL					\$690

Our enclosed check for \$ 690.00 covers the government filing fee and our enclosed check in the amount of \$40.00 covers the assignment filing fee..

We authorize the Commissioner to charge any additional filing fees under 37 C.F.R. § 1.16 or application processing fees under 37 C.F.R. § 1.17, which may be required now or during the pendency of this application, or credit any overpayment to Account No. 16-2230. We enclose a duplicate copy of this sheet.

Please stamp the filing date on the enclosed post card and return it to us.

Sincerely,



Guy Porter Smith
OPPENHEIMER WOLFF & DONNELLY LLP

Enclosures

U.S. PATENT APPLICATION OF

Zhejie Liu

QiDe Zhang

Shixin Chen

Teck Seng Low

FOR AN INVENTION ENTITLED:

***SPINDLE MOTOR WITH AN AERODYNAMIC AND
HYDRODYNAMIC BEARING ASSEMBLY***

*DOCKET NO. 15939-18
SHEETS OF DRAWINGS: 5*

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SPINDLE MOTOR WITH AN AERODYNAMIC AND HYDRODYNAMIC BEARING ASSEMBLY

Field of the Invention

The present invention relates to a spindle motor and, in particular, to a bearing assembly of such a motor.

Background of the Invention

A spindle motor in general comprises a stator and a rotor, including a hub for supporting an optical or magnetic disc or the like. A bearing assembly is provided between the stator and the rotor and consists of a journal bearing and a thrust bearing. It is known to provide both the thrust and journal bearings as hydrodynamic bearings. However, lubricant used in such bearings can be somewhat difficult to seal and may contaminate the recording medium of the disc mounted to the rotor if fluid migration from the bearing occurs. Hydrodynamic bearings also have a disadvantage of high frictional losses during operation.

Aerodynamic bearings may be utilised instead of hydrodynamic bearings, to reduce frictional losses and allow for increased operating speeds, however, aerodynamic bearings have relatively low bearing stiffness.

A spindle motor, as disclosed in US 4200344, ameliorates the above disadvantages by using a liquid lubricant for the journal bearing only and providing an aerodynamic for the thrust bearing. However, the thrust bearing is only adapted to function in a uni-directional manner, which is not desirable for practical disc drives.

US 5358339 also discloses a spindle motor with a liquid journal. That motor includes two flat thrust plates at either end of the journal bearing to thereby provide for bi-direction axial support. A disadvantage of such a motor though is that the thrust plates, which need

to be of a sufficient size to generate suitable aerodynamic pressure to form a gas bearing, increase the overall volume dimension and space requirements of the motor.

Summary of the Invention

The present invention seeks to address the above mentioned disadvantages.

In accordance with the invention, there is provided a spindle motor including a stator component, a rotor component, including a hub for supporting one or more discs, and a bearing assembly between the components, formed of a journal bearing and a thrust bearing, wherein the journal bearing is an aerodynamic bearing and the thrust bearing is adapted to function in a bi-directional manner and includes an annular member projecting radially from one of the components into an associated recess formed in the other of the components.

Preferably, the journal bearing is formed between a shaft of one of the components and an associated sleeve of the other one of the components and the shaft is provided with a passage extending therethrough for providing air flow through the motor to the aerodynamic bearing, so as to allow air to be entrained into the journal bearing during operation.

Preferably, the annular member has two opposed bearing faces arranged adjacent corresponding bearing surfaces of the recess, and a hydrodynamic bearing is formed between the respective bearing faces and surfaces.

Preferably, the bearing surfaces diverge from the bearing faces adjacent the shaft so that liquid between the annular member and the recess is retained therebetween by surface tension seals.

Preferably, the shaft includes a thrust bearing passageway which includes a port opening adjacent the annular member, between the thrust bearing and the journal bearing for equalising air pressure at either side of the journal bearing.

Preferably, the shaft is fixed relative to the stator and the sleeve forms part of the rotor.

Brief Description of the Drawings

Figure 1 is a cross-sectional view of a spindle motor according to a preferred embodiment of the present invention;

Figure 2 is a detailed cross-sectional view of the spindle motor shown in Figure 1;

Figure 3 shows two arrangements of a non-contact liquid seal for the liquid-filled thrust bearing of the spindle motor shown in Figure 1;

Figure 4 is a cross-sectional view of a modified spindle motor; and

Figure 5 is a detailed cross-sectional view of the gas-filled thrust bearing and the liquid-filled journal bearing of the spindle motor shown in Figure 4.

Detailed Description of a Preferred Embodiment

A preferred embodiment of the present invention is shown in Figure 1. The motor 10 illustrated is of the brushless type but the present invention may also be used with other types of motors. The spindle motor 10 comprises a stator component 16 and a rotator component 18.

The stator component 16 comprises a base assembly 20, a cylindrical shaft 22, and a stator 24 which comprises a lamination core 26 and armature windings 28. An annular member 30 is coaxially mounted near a free end 32 of the shaft 22.

The rotor component 18 comprises a cylindrical sleeve 34 which is rotatable about the shaft 22, first and second thrust sleeve members 36, 38, which are fitted to the sleeve 34 to define a recess for receipt of the annular member 30, and a rotatable hub 14. The hub 14, preferably made of aluminium alloys forms a housing 12 for accommodating all the components of the motor. The hub 14 houses the thrust sleeve members 36, 38 and has a

cylindrical hole 40 at the top end to accommodate the shaft 22.

The stator component couples with the rotor component such that a gap 42 is formed between the outer surface of the lamination core 26 and the inner surface of a rotor 44 which is mounted to the hub 14. The rotor 44 comprises ring-shaped magnetic poles 46 and a rotor back iron 48 which is bonded to the inner surface of the hub 14. The rotor back iron 48 provides a magnetic path for the magnetic field of the motor 10. Terminal leads from the armature windings 28 are fed from the motor housing 12 through a terminal lead aperture 50 and are connected to a power supply via a motor control circuit. The armature windings 28 are energised according to control logic which regulates speed of the motor 10. When the armature windings 28 are energised, an electromagnetic torque is developed by the interaction between magnetic fields of the magnetic poles 46 and the armature windings 28, causing rotation of the hub.

The preferred embodiment of the present invention provides a liquid-filled thrust bearing 52 and a gas-filled journal bearing 54 to support the axial and radial load during rotation.

For that purpose, the shaft 22 further comprises a journal bearing portion, defining an inner surface 56 of the journal bearing 54. A mating surface of the journal bearing 54 is formed on an inner surface of the sleeve 34 and defines an outer surface 58 of the journal bearing 54 which is radially spaced from the inner surface 56 of the journal bearing 54 to form a journal bearing clearance 60. The journal bearing clearance 60 is filled with a gas, preferably air, for lubrication. A gas passageway is provided with an opening 62 substantially midway along the length of the journal bearing 54 for assisting the flow of gas through the motor 10 to the bearing 54 and, in particular, for preventing stagnation of the flow of gas which can cause difficulty in starting rotation of the journal bearing 54. Aerodynamic pressure is generated in the journal bearing 54 during the operation thereof and is used to support radial loads of the shaft 22. Grooves 64, preferably in a herringbone pattern, are provided on the inner surface 56 of the journal bearing 54 to enhance

performance, and, in particular, bearing stiffness.

Axial loads of the shaft 22 are supported by the thrust bearing 52 which produces hydrodynamic pressure during the operation thereof. The thrust bearing 52 comprises the annular member 30 in the form of a thrust bearing plate 66 which is mounted coaxially near the free end of the shaft 22 and which includes a first thrust face 68 and a second thrust face 70. First and second bearing surfaces 72, 74, corresponding to the first and second thrust faces 68, 70, are formed on interior surfaces of first and second thrust sleeve members 36, 38 respectively, which define the recess 76 for receipt of the bearing plate 66. The recess 76 is dimensioned to be slightly larger than the thrust bearing plate 66 which resides therewithin, such that a thrust bearing clearance 78 is defined. The thrust bearing clearance 78 is filled with a liquid lubricant, the lubricant being sealed within the clearance 78 by non-contact sealing means in the form of first and second surface tension seals 80, 82. The formation of the surface tension seals 80, 82 is facilitated by an increase in the thrust bearing clearance 78, on both sides of the thrust bearing plate 66, at a portion 84 thereof which is substantially adjacent to the shaft 22. The increase in thrust bearing clearance 78 may be achieved by forming tapered portions 86 in the bearing surfaces 72, and/or by forming annular grooves 88 in the thrust faces 68, 70. Annular grooves may also be formed in the shaft 22 adjacent the thrust bearing plate 66. The surface tension seals 80, 82 ensure that the liquid does not migrate from the thrust bearing clearance 78, whilst achieving relatively minimal frictional losses when compared to typical *contact* type seals.

A thrust bearing gas passageway 90 is provided to reduce the effect that the aerodynamics of the journal bearing 54 have on the surface tension seals 80, 82. In particular, the thrust bearing gas passageway 90 maintains equilibrium between the first and second surface tension seals 80, 82 so that the liquid remains within the thrust bearing clearance 78. Preferably, the surfaces adjacent to the surface tension seals 80, 82 are provided with an anti-migration coating 92 to assist in the prevention of migration of liquid from the thrust bearing clearance 78. When the hub is rotated, especially at high speeds, hydrodynamic pressure is generated in the thrust bearing 52 and is preferably sufficient to

solely support the hub in at least both axial directions. Grooves 94 are provided at the thrust faces 68, 70 and/or the bearing surfaces 72, 74 to facilitate the formation of hydrodynamic pressure. The thrust bearing plate 66 may be radially outwardly tapered, in which case the thrust bearing 52 also offers some radial support to the sleeve 34 of the hub.

In Figures 4 and 5, the spindle motor 110 is provided with a gas-filled thrust bearing 152 and a liquid-filled journal bearing 154. During rotation of the hub, support is provided at least axially by aerodynamic pressure in the thrust bearing 152, and radially by hydrodynamic pressures in the journal bearing 154. Figure 5 shows an enlarged view of surface tension seals 180, 182 which are provided at a first end 100 and at a second end 102 of the journal bearing 154 for containing the liquid lubricant in the journal bearing 154. The formation of the seals 180, 182 is facilitated by an increase in the journal bearing clearance 178 at both the first end 100 and the second end 102 of the journal bearing 154. The increase in the journal bearing clearance 178 may be provided by outwardly tapering the outer surface 158 of the journal bearing 154 and/or by forming annular grooves 194 in the shaft 122, at both the first end 100 and at the second end 102 of the journal bearing 154. Surfaces adjacent to the dynamic tension seals 180, 182 may be provided with an anti-migration coating 192 to assist in the prevention of the migration of liquid from the journal bearing 154. A radially outward passageway 106 is provided from the thrust bearing plate-receiving cavity 108 to the motor housing 112. The radially outward passageway 106 allows smooth circulation of gas flow and prevents stagnation of gas flow in the thrust bearing 152.

As may be appreciated, the above described combinations of journal and thrust bearings allow for the advantageous use of both aerodynamic and hydrodynamic bearings whilst providing reliable support of the rotor component relative to the stator component regardless to the orientation of the spindle motor and/or to shocks, and minimising space requirements of the motor, as compared to, for example, the teachings of US 5358339.

Although the present invention has been described with reference to a preferred embodiment, it will be apparent to those skilled in the art that changes and modifications may be made in

form and detail without departing from the spirit and scope of the invention.

CLAIMS:

1. A spindle motor including a stator component, a rotor component, including a hub for supporting one or more discs, and a bearing assembly between the components, formed of a journal bearing and a thrust bearing, wherein the journal bearing is an aerodynamic bearing and the thrust bearing is adapted to function in a bi-directional manner and includes an annular member projecting radially from one of the components into an associated recess formed in the other of the components.
2. A spindle motor as claimed in claim 1, wherein the annular member has two opposed bearing faces arranged adjacent corresponding bearing surfaces of the recess, and a hydrodynamic bearing is formed between the respective bearing faces and surfaces.
3. A spindle motor as claimed in claim 2, wherein the journal bearing is formed between a shaft of one of the components and an associated sleeve of the other one of the components and the shaft is provided with a passage extending therethrough for providing air flow through the motor to the aerodynamic bearing, so as to allow air to be entrained into the journal bearing during operation.
4. A spindle motor as claimed in claim 3, wherein the bearing surfaces diverge from the bearing faces adjacent the shaft so that liquid between the annular member and the recess is retained therebetween by surface tension seals.
5. A spindle motor as claimed in claim 3 or 4, wherein the shaft includes a thrust bearing passageway which includes a port opening adjacent the annular member, between the thrust bearing and the journal bearing for equalising air pressure at either side of the journal bearing.
6. A spindle motor as claimed in any one of claims 3 to 5, wherein the shaft is fixed relative to the stator and the sleeve forms part of the rotor.

7. A spindle motor as claimed in claim 4, wherein the annular member or shaft includes an annular groove to either side of the annular member to further assist in formation of the surface tension seals.

ABSTRACT

SPINDLE MOTOR WITH AN AERODYNAMIC AND HYDRODYNAMIC ASSEMBLY

A spindle motor (10) including a stator component (16), a rotor component (18), including a hub (14) for supporting one or more discs, and a bearing assembly between the 5 components, formed of a journal bearing (54) and a thrust bearing (52), wherein the journal bearing (54) is an aerodynamic bearing and the thrust bearing is adapted to function in a bi-directional manner and includes an annular member (30) projecting radially from one of the components into an associated recess (76) formed in the other of the components. Preferably, the annular member has two opposed bearing faces (68,70) arranged adjacent corresponding 10 bearing surfaces of the recess, and a hydrodynamic bearing is formed between the respective bearing faces and surfaces.

(Figure 1 & 2)

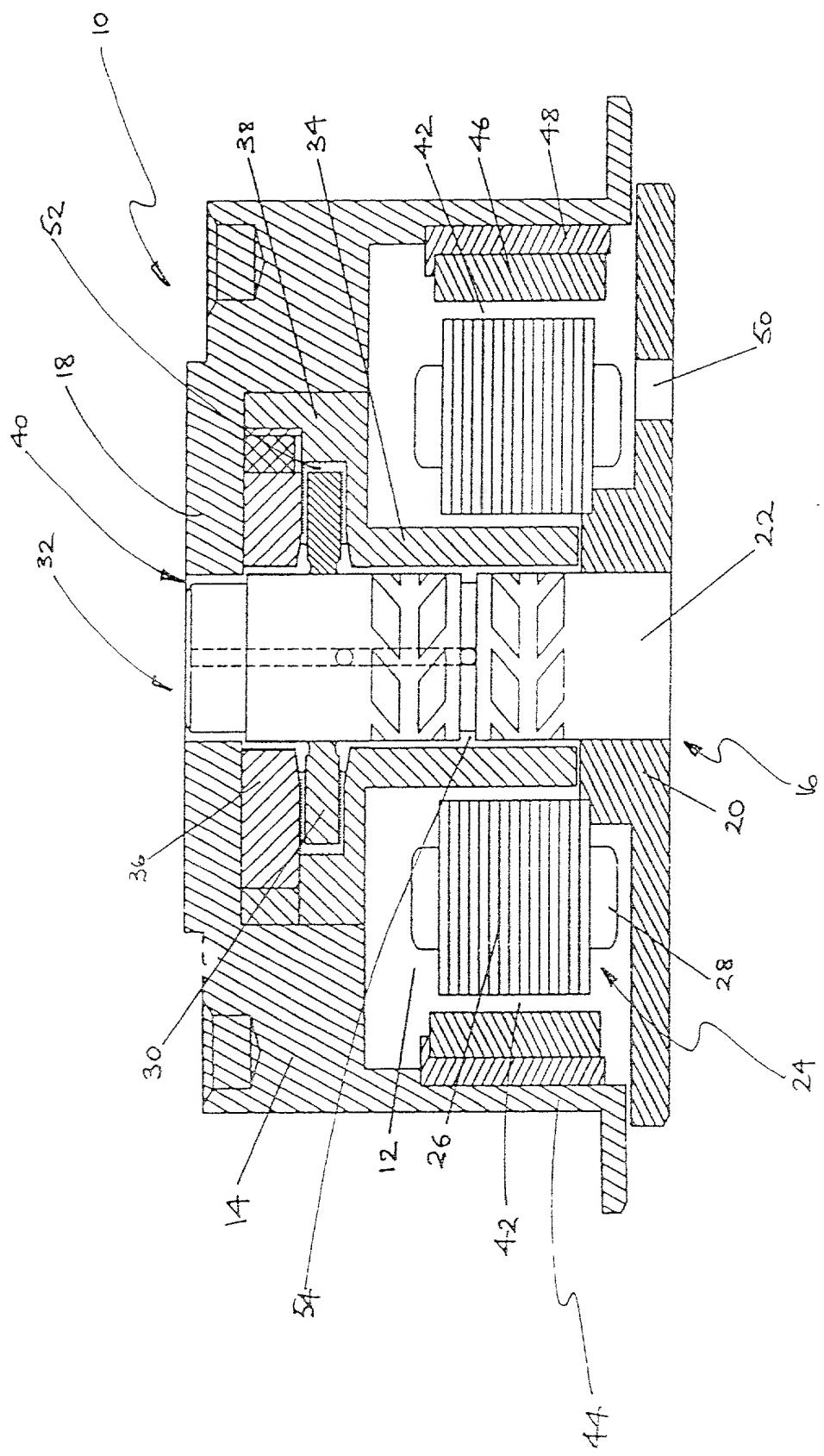


Fig. 1

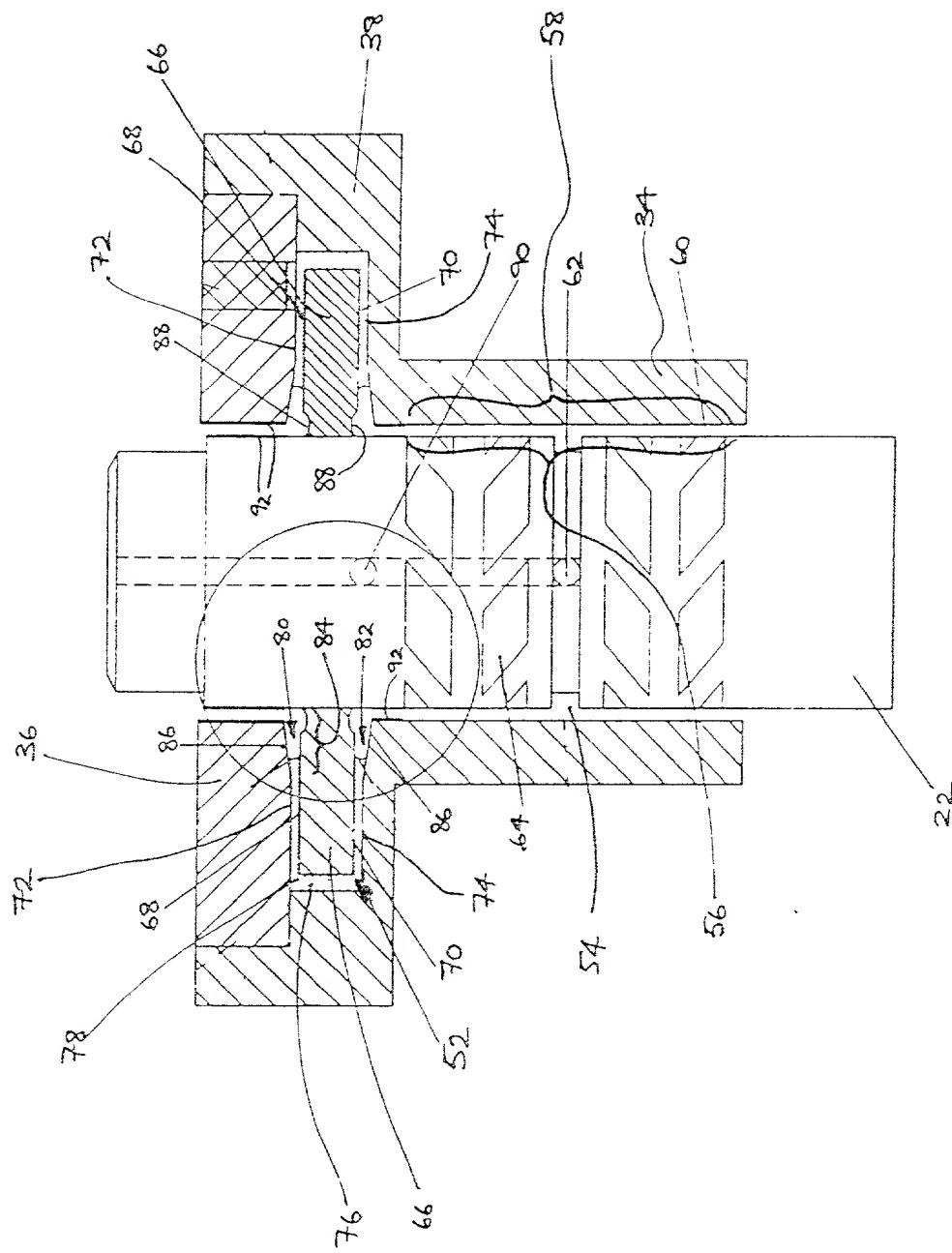


Fig. 2

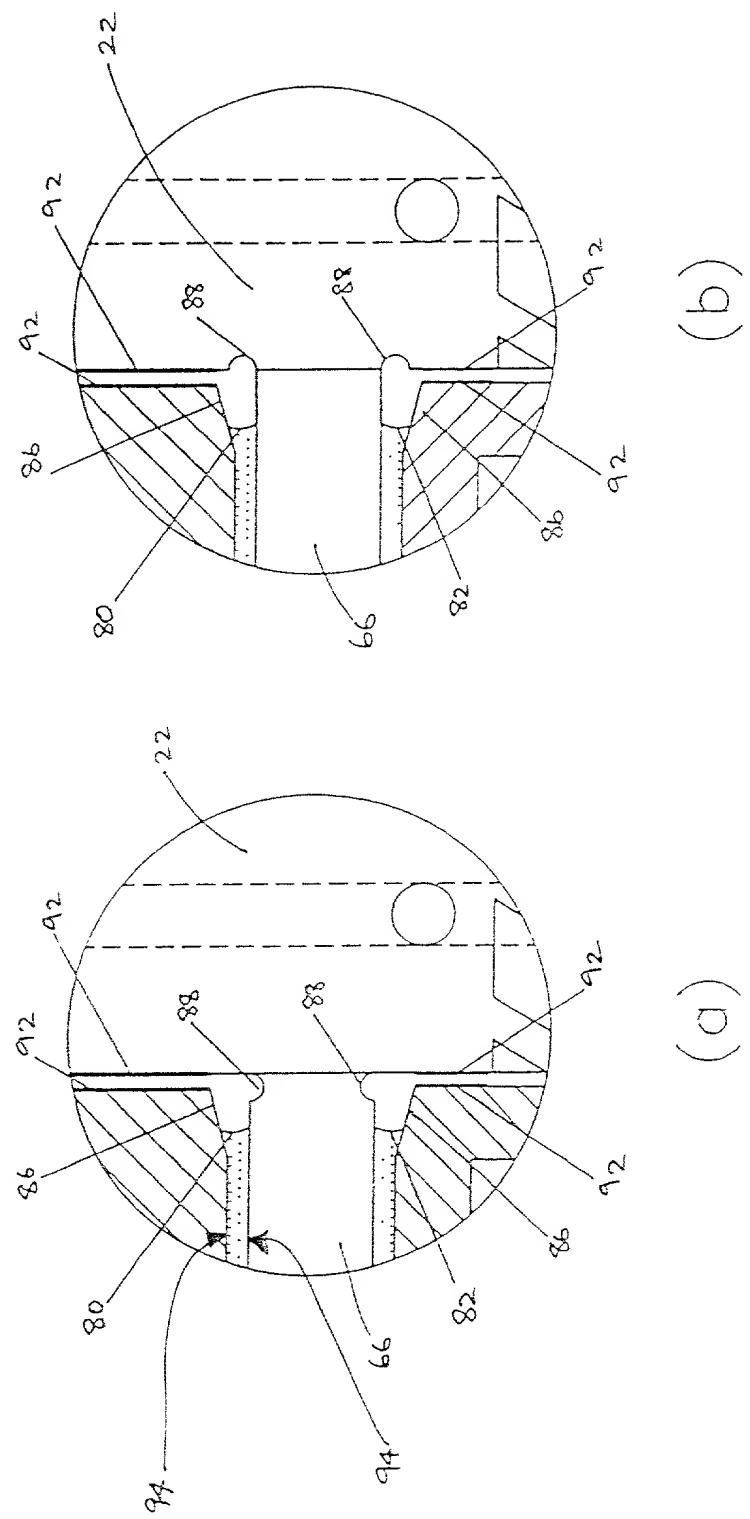


Fig. 3

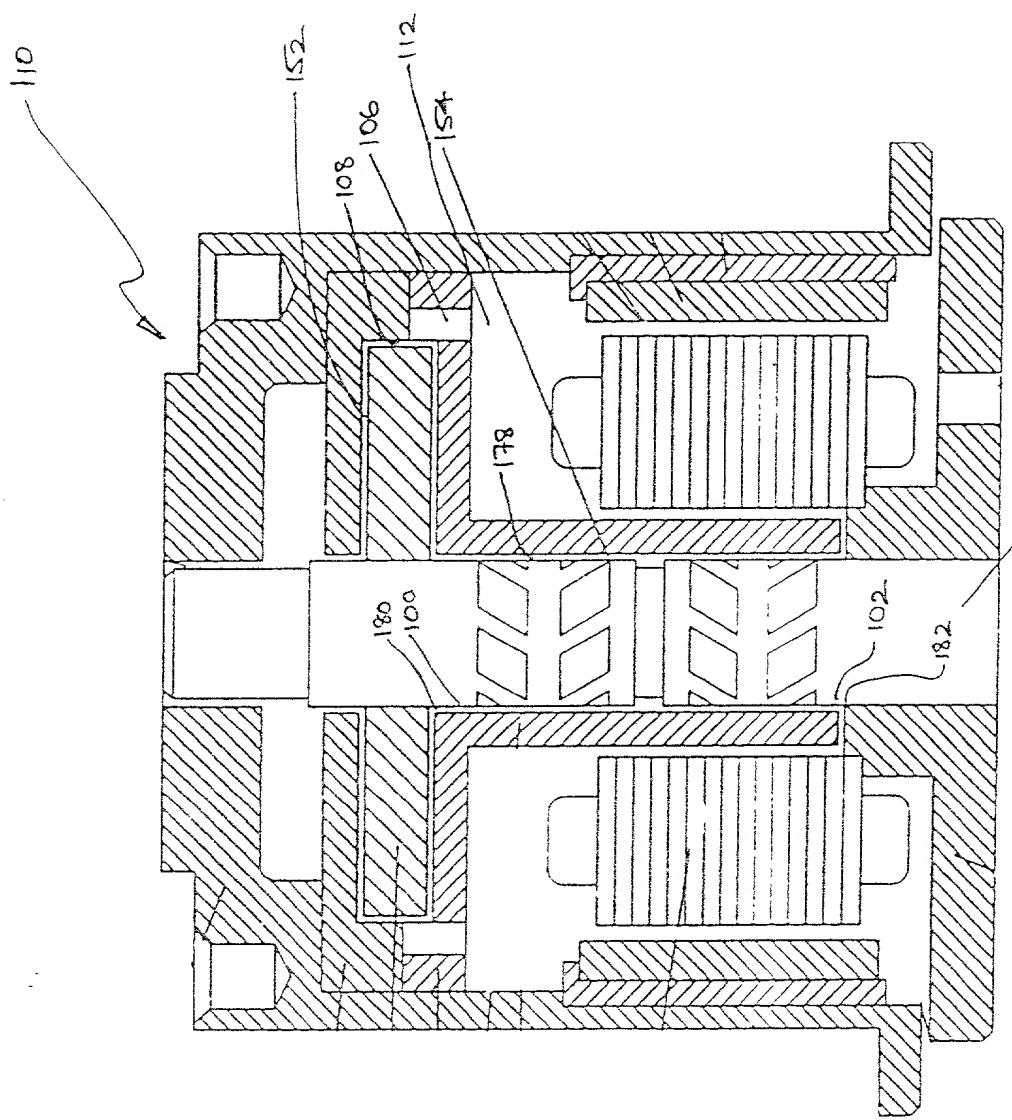


Fig. 4

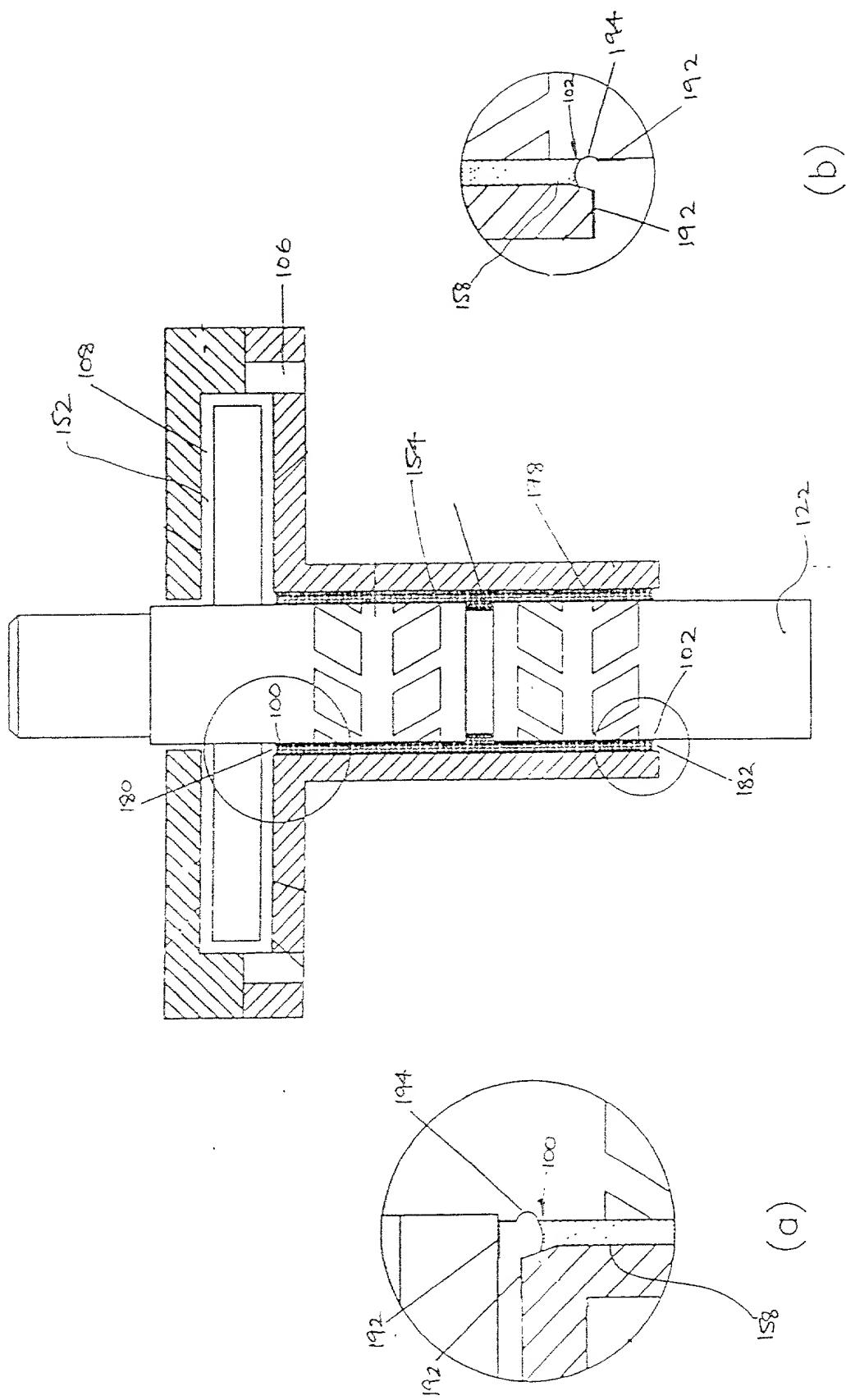


Fig. 5

DECLARATION AND PETITION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled SPINDLE MOTOR WITH AN AERODYNAMIC AND HYDRODYNAMIC BEARING ASSEMBLY, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application of which priority is claimed.

Prior Foreign Application(s)

			Priority Claimed	
9906597-1 (Number)	Singapore (Country)	23 December 1999 (Day, month, year filed)	X Yes	No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) Filing Date (Status: Patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Please send all correspondence to:
OPPENHEIMER WOLFF & DONNELLY LLP
2029 Century Park East, Suite 3800
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Attn: George L. Fountain
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Wherefore I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification and claims, declaration, and this petition.

Full name of sole or first inventor: Zhejie LIU

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Citizenship: Singaporean

Post Office Address: Same as above

Full name of second inventor: QiDe ZHANG

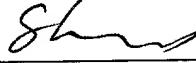
INVENTOR'S SIGNATURE  DATE 23-03-2000

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Citizenship: Singaporean

Post Office Address: Same as above

Full name of third inventor: Shixin CHEN

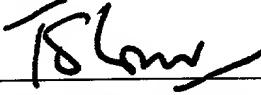
Inventor's signature  Date 23/03/2000

Residence: c/o Data Storage Institute of DSI Building, 5 Engineering Drive 1, (off Kent Ridge Crescent, NUS), Singapore 117608

Citizenship: Singaporean

Post Office Address: Same as above

Full name of fourth inventor: Teck Seng LOW

INVENTOR'S SIGNATURE  DATE 27/03/2000

Residence: c/o Data Storage Institute of DSI Building, 5 Engineering Drive 1, (off Kent Ridge Crescent, NUS), Singapore 117608

Citizenship: Malaysian

Post Office Address: Same as above

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Applicant: Zhejie LIU, et al.

Serial No.: To be Assigned

Filed: Herewith

**Title: SPINDLE MOTOR WITH AN
AERODYNAMIC AND HYDRODYNAMIC
BEARING ASSEMBLY**

POWER OF ATTORNEY

Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

DATA STORAGE INSTITUTE, having become the owner of all rights in and to the above-identified application by virtue of an Assignment executed by the inventors concurrently with the execution of the application, said Assignment:

being submitted herewith for recording; or
 having been previously recorded with the U.S. Patent and Trademark Office, at reel ___ and frame(s)

hereby revokes all prior powers and now appoints:

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G.P. SMITH, Reg. 20,142	A.P. BLOCK, Reg. 35,450	G.L. FOUNTAIN, Reg. 36,374
G.E. LANDE, Reg. 22,222	M.E. HARRIS, Reg. 26,690	L.C. CULLMAN, Reg. 39,645
A.C. ROSE, Reg. 17,047	K.A. MACLEAN, Reg. 31,118	A.C. LOGAN, Reg. 33,950
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C. DARROW, Reg. 30,166	J.W. INSKEEP, Reg. 33,910	J.M. KALIS, Reg. 37,650
M.E. BROWN, Reg. 28,590	C. ROSENBERG, Reg. 31,464	C.J. LERVICK, Reg. 35,244

whose address is:

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Attention: George L. Fountain, Esq.

their attorneys to prosecute said application and to transact in connection therewith all business in the Patent and Trademark Office and before competent International authorities.

The undersigned has reviewed all the documents in the chain of title of the patent application identified above and, to the best of undersigned's knowledge and belief, title is in the assignee identified above.

The undersigned, whose title is supplied below, is empowered to act on behalf of the assignee.

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

DATA STORAGE INSTITUTE

Date: 22/3/00

By Chong Tow CHONG
Name: Chong Tow CHONG
Title: Director